FINAL REPORT

For Cooperative Agreement No. NCC 2-667 between the NASA/Ames Research Center and the Lunar and Planetary Laboratory, University of Arizona.

Title of Project: Calibration of GaAs Photomultiplier Tubes for Standardization of the SSPM Detector

Original Principal Investigator: Dr. Wieslaw Z. Wisniewski
Senior Research Associate

(The LPL regrets Dr. Wisniewski's untimely death on Feb. 28, 1994.)

Reporting Principal Investigator: Dr. Robert S. McMillan
Assistant Research Scientist
Lunar and Planetary Laboratory
University of Arizona
Tucson, AZ 85721

Phone 602/621-6968

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Description of Work:

This cooperative program was to calibrate the sensitivity of a photomultiplier tube in support of the standardization of the sensitivity of another detector under development at NASA/Ames, the Solid State Photomultiplier (SSPM).

Technique:

A Hamamatsu GaAs (Cs) photomultipier R943-02 and a Products for Research Thermoelectric Cooler were provided by NASA Ames Research Center. These units were incorporated into a photometer and used by the original PI, Dr. Wisniewski, for photoelectric observations on the NASA 1.5-m telescope on Mt. Lemmon near Tucson, Arizona. This instrument was used during approximately 30 nights per year (out of about 100 scheduled nights). A more detailed description of the instrument was given in a previous progress report. Photometric data were reduced manually by Wisniewski.

Hamamatsu R943-02:

This tube with a GaAs(Cs) photocathode, is virtually identical in spectral response to the most used in astronomy e.g., the RCA C31034, but is more sensitive across the spectrum, having a larger and more uniform sensitive area. A large cathode area and a small cathode inclination angle make optical alignment by far easier. For safety reason the tube was never used under high voltage exceeding - 2000 V (2200 is allowed by factory specification) or with sources brighter than 200000 c/s. Over time, the R943-02 was very quiet, with a dark current of 3-6 Hz in winter and 30 Hz in summer. This seasonal change was due to the thermoelectric cooler maintaining a nominal 40 deg C differential temperature from ambient. Perhaps at lower temperatures the tube would have even lower dark current. No transformation problems were encountered using the standard reduction procedure. Typical transformation equations were:

$$B\text{-}V = \text{const} + 1.090\,(b\text{-}v) - 0.11a$$

$$V = \text{const} - 0.043\,(B\text{-}V) - 0.19a + v$$

$$U\text{-}V = \text{const} + 1.061\,(u\text{-}v) - 0.30a$$

$$V\text{-}W = \text{const} + 0.927\,(v\text{-}w) - 0.05a$$

$$V\text{-}X = \text{const} + 0.985\,(v\text{-}x) - 0.07a$$

where a is airmass and the natural (instrumental) system indices are lower case.

Counts/sec measured at the 1.5 meter NASA telescope for A0 and K0 stars are given below. In the last column are given standard fluxes incident on the Earth atmosphere in watts/mE2 Hz for a 0 magnitude A0 star.

	Star SA 51-3 A0 V=9.78 c/s	Star SA 51-2 K0 V=9.54 c/s	Star A0 V=0 Watt/mE2Hz
Filter(micron)			
U (0.36)	35910	10892	1.88 E-23
B (0.44)	187904	104506	4.64 E-23
V (0.55)	86235	103052	3.95 E-23
W (0.70)	53994	116903	2.87 E-23
X (0.86)	37965	107946	2.36 E-23

Since this project was terminated by NASA/Ames, the equipment belonging to NASA/Ames was shipped on November 14, 1994 to the Technical Officer, Dr. John H. Goebel. Since no further measurements were made after Wisniewski's death, the residual funds in the grant, after paying for the shipping of the equipment, are being returned to NASA/Ames Research Center.

Scientific Investigations:

This instrument was extensively used by Wisniewski to obtain lightcurves and colors for small asteroids. Particular attention was paid to long term monitoring of 243 Ida in preparation for the flyby with the Galileo spaceship in 1993. Such data obtained from the ground was used to define pole orientation and to deduce object shape to help orient the spacecraft for the most efficient use of the limited flyby observing time. Such a unique encounter offers us a rare opportunity to check and calibrate theoretical models derived from observations of asteroid properties. In addition, whenever possible, the physical data of newly discovered Earth approaching asteroids are being obtained. The Earth-approacher 1992 NA was photometered by Wisniewski shortly after its discovery (Wisniewski and Harris 1994). Some 20-odd asteroids of special interest had been measured taxonomically by Wisniewski.

Because of an exceptional opportunity, many nights were dedicated in 1992 December and 1993 January (18 and 8 respectively) to monitor 4179 Toutatis in 5 colors. During this apparition this Earth approaching asteroid passed Earth at the distance of 0.024 AU and showed an entirely unprecedented range of viewing geometries. The object was observable for almost 3 hours near 100 deg phase angle and it was possible to monitor it all the way to 0 phase angle. This work was a part of an international effort. The rotation period must be at least 7 days. However, judging by the complex lightcurve it could be as long as 15 days. The color change observed by Wisniewski with the Ames equipment, in particular in u-v and v-x, is the largest of any asteroid. The unusually rapid variation for such a slow rotator of 0.1 mag/hour is noticeable on 1992 Dec 11. Similar variability on the rising part of the lightcurve was noticed by Tholen (private communication). Wisniewski, W. Grundy, and M. Hicks obtained two excellent lightcurves of Geographos in 1993 December (Magnusson et al. 1994 in press).

Publications:

Binzel, R. P., Slivan, S. M., Magnusson, P., Wisniewski, W. Z., Drummond, J., Lumme, K., Barucci, M. A., Dotto, E., Angeli, C., Lazzaro, D., Mottola, S., Gonano-Beurer, M., Michalowski, T., De Angelis, G., Tholen, D. J., Di Martino, M., Hoffmann, M., Geyer, E. H., & Velichko, F. 1993, Icarus **105**, 310-325: "Asteroid 243 Ida: Groundbased photometry and a pre-Galileo Physical Model".

Magnusson, P., Barucci, M. A., Binzel, R. P., Blanco, C., Di Martino, M., Goldader, J. D., Gonano-Beurer, M., Harris, A. W., Michalowski, T., Mottola, S., Tholen, D. J., and Wisniewski, W. Z. 1992, Icarus **97**, 124-129: "Asteroids 951 Gaspra: Pre-Galileo Physical Model".

Ostro, S. J., and Wisniewski, W. Z. 1992, in Asteroids, Comets, and Meteors 1991, Eds. A. W. Harris and E. Bowell. 447-450: "The Shape of Asteroid 1917 Cuyo".

Rabinowitz, D. L., Gehrels, T., Scotti, J. V., McMillan, R. S., Perry, M. L., Wisniewski, W. Z., Larson, S. M., Howell, E. S., & Mueller, B. E. A. 1993, Nature **363**, 704-706: "Evidence for a near-Earth asteroid belt".

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Wisniewski, W. Z., and Harris, A. W. 1994, in IAU Symp. #160; Asteroids, Comets, and Meteors 1993: "The complex lightcurve of 1992 NA", in press.